Clinical Decision-Making for Dental Caries Management

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Preceding presentations at this consensus conference have reviewed the scientific literature on diagnosis and management of dental caries, indicators of risk, primary prevention of dental caries, and methods of arresting, reversing, or treating early carious lesions. There is a vast scientific literature on these topics, and the practicing clinician may find that such an overwhelming mass of data may be difficult to identify, assess, and translate into useful knowledge to improve his/her clinical practice.

The purpose of this paper is to describe why a clinical decision-making framework is useful, to outline the characteristics and steps of clinical decision-making, to discuss the potential application of clinical decision-making to diagnosis and management of dental caries, and to highlight the advantages and limitations of clinical decision-making. Following papers will examine these rationales to describe the various clinical decision-making approaches for coronal caries in the primary dentition and coronal and root caries in the permanent dentition, as well as offering frameworks for integrating the various components that might affect the clinical situation.

Problem solving in the clinical environment

There are a number of reasons why clinical decision-making may be a useful tool in the diagnosis and management of dental caries. First, we have seen from the previous presentations that while we know a lot about dental caries, there is much we do not know. Information is imperfect, yet dentists are expected to make decisions about patient care every day, decisions that will be based at least partially on probabilistic—as contrasted with definitive—information.

Second, patients vary in clinically important ways: in clinical presentation, in the course of disease and health, and in values and preferences for treatments and outcomes. Uncertainty

abounds in their risk for dental caries; in diagnostic and prognostic information; in the efficacy and effectiveness of many preventive, diagnostic, and treatment alternatives; and in the outcomes associated with clinical strategies. Research cannot, and likely will never be able to, answer all important, clinically relevant questions. Funding constraints, ethical issues, and logistics prohibit conducting a randomized clinical trial on every important question.

Third, the evidence base that informs decisions about diagnosis and management of dental caries is evolving. New diagnostic, preventive, and therapeutic technologies are constantly being introduced, and the scientific literature continues to expand.

Finally, there are often competing goals and multiple perspectives that influence the clinical decision. Patients and their families may have different values and preferences for treatment options and outcomes than practitioners. Clinical decision-making provides a framework for assessing the impact of these different perspectives on various clinical strategies.

Explanatory models

Two types of explanatory models have been used in clinical decision-making. The first type identifies the mechanisms, values, and concepts underlying diagnostic thinking, and then characterizes the relationships between the use of specific concepts and strategies leading to more effective diagnostic and treatment performance. This first model aims to *accurately represent and describe* the process of decision-making. That is, how is it that dentists actually make diagnostic and treatment decisions? How do dentists process information to reach a diagnosis? What factors are most important in reaching a treatment decision? How do dentists incorporate patient preferences into clinical decisions?

A second type of model emulates the pathways used in the decision-making process in diagrammatic schemes that portray the diverse options available to the clinician. Diagrammatic schemes frequently serve as aids to decision-making. The second approach aims to *symbolically represent and prescribe* the process of decision-making. That is, how should a decision be made based on the available evidence about the alternative strategies? What impact does the sensitivity and specificity of diagnostic tests have on adjusting the likelihood of disease? How do data on the efficacy and effectiveness of alternative treatment strategies influence clinical decisions? How can patient preferences and outcomes be incorporated into the decision process? What influence do they (or should they) have on the decision process?

For several reasons, the remainder of this paper focuses on prescriptive models that are meant to symbolically represent how decisions should be made given available evidence. The first reason is that the Consensus Development Conference has adopted an evidence-based approach. Prescriptive decision models allow for explicit incorporation of diagnostic uncertainties, effectiveness, and patients' preferences for outcomes of interventions. Second, such models provide a means for quantifying the effects of different diagnostic and treatment strategies on outcomes. Finally, prescriptive models suggest how dentists should make decisions to optimize expected outcomes based on available data. The treatment of choice in this model may change, even for the same intervention, based upon patients' preferences.

Clinical decision-making

Within the narrower scope of the present paper, clinical decision-making—explicit use of information to quantify probabilities and outcomes to analyze decisions under conditions of uncertainty—can provide a framework to analyze the impact of uncertainty of clinical

information.[1] It is explicit in that it forces the decision-maker to break down the decision problem into component parts that can be analyzed individually before being recombined in a systematic way to suggest a preferred strategy. It is quantitative in that evidence and beliefs about key uncertainties must be identified and numerical estimates of probabilities and outcomes must be assigned. It is prescriptive in that it seeks to guide clinical decisions in ways that achieve optimal outcomes based on the structure of the decision problem, the underlying assumptions and uncertainties, and the values and preferences for outcomes. Clinical decision-making does not eliminate the uncertainty associated with clinical information or guarantee a "correct" strategy. Rather, assumptions about the clinical situation and uncertainties associated with probabilities and outcomes are made clear, so their impact can be assessed. For example, the study of diagnostic processes entails scrutinizing and structuring the acquisition and organization of pieces of information (a combination of psychosocial and biomedical items) without set rules to follow, nor an established beginning or end to the process.[2] There are no external parameters against which the accuracy of diagnosis can be measured until the outcome of the next step, management and treatment, provides some validation of the diagnostic decision.[3]

Clinical decision-making seeks to quantify the effect that an input (*e.g.*, clinical and laboratory information, diagnosis, risk assessment, treatment strategy) has on an output (*e.g.*, an outcome). Such models are often based on statistical methods and conditional probability theories (*e.g.*, Bayes' theorem). The aim is to find a combination of pieces of information to produce a diagnosis, treatment decision, or outcome, assembling them according to importance in the case. The relevance of each factor is decided by attaching probability values based on previous clinical and epidemiological experience. Thus, clinicians estimate a probability

criterion on the basis of given values of a set of predictors.[4,5] According to Bayes' theorem, clinical decision-making depends on the prior probabilities of the likely diagnoses, the signs and symptoms present in a case, and their probability of joint occurrence.[6]

Steps in clinical decision-making

Clinical decision-making for dental caries management may be described in four basic steps (Table 1). In the first step, the clinical question must first be identified and characterized. One identifies the relevant population for study (*e.g.*, young children, adolescents, adults, elderly); the alternative diagnostic, preventive, or management options; and possible clinical states of the patient at different points in time (*e.g.*, What happens if the tooth is restored? What happens if it is not restored?). For clinical decision-making to be useful, the clinical question must involve choosing between two or more clinical strategies with meaningful tradeoffs in the choice. All other things equal, clinical decision-making may not aid the clinician if the effectiveness or outcomes of two different strategies are equivalent. One must identify possible clinical information that will fully characterize the decision problem (*e.g.*, risk factors, previous caries experience, fluoride exposure history). Clinical questions may focus on such topics as detecting a carious lesion, including diagnostic techniques and clinical examinations; characterizing caries risk status; primary, secondary, and tertiary prevention of dental caries; and arresting or reversing a carious lesion.

In the second step, the decision problem is structured to address the relevant clinical problem using a model or decision tree that represents the logical and temporal sequence of caries management. The decision tree should be sufficiently complex to reflect important events and outcomes associated with the clinical problem, yet simple enough to be understandable and

practical as a decision-making aid. A well-defined clinical starting point must be specified (*e.g.*, caries free, white-spot lesions, cavitation), including such factors as age and sociodemographic characteristics; caries risk status; prior and current caries experience; behavioral factors; diet; fluoride exposure; and general health status, including use of xerostomia-inducing medications and presence of diseases that may affect salivary gland function. The relationship of relevant diagnostic, preventive, and/or treatment strategies should be identified, including "no treatment" choices, and important outcomes—biological, clinical, and psychosocial—described.

Decision trees are one of the fundamental analytical tools for decision analysis and are a way of displaying the proper temporal and logical sequence of a clinical decision problem.[1] Such trees are a diagrammatic framework of nodes and branches from which the clinician makes a choice from a set of actions and then proceeds through the selected branch onto the next node. Decision trees highlight three structural components of the clinical scenario under consideration: alternative actions available to the clinician are identified; events that follow from and are affected by the alternatives; and the outcomes for the patient that are associated with each possible scenario of actions and consequences.

A simple decision tree for initial caries management is shown in Figure 1. In this example, a person at low risk for dental caries is found to have an early carious lesion approaching the DEJ on a routine recall examination. The clinician may decide to follow one of several treatment strategies. A point in time at which the clinician decides on a course of action is referred to as a decision or choice node and is represented by a small square . Probabilistic events, such as progression of the carious lesion or reversal, are referred to as chance nodes and are shown by small circles. These clinical events denote points in time at which one of several possible events may take place that are beyond the control of the clinician.

Decisions between two or more strategies should be guided by the expected outcomes associated with a strategy; those strategies yielding better expected outcomes are preferred to those that yield worse expected outcomes. In this example, the clinician may choose to (1) attempt remineralization of the carious lesion, (2) restore the carious lesion, or (3) evaluate the lesion at a future date without further treatment (*e.g.*, watchful waiting). Outcomes associated with each strategy include the presence or absence of a carious lesion and the results of the treatment strategy (*e.g.*, a restoration).

In the third step, the clinician gathers the information needed to answer the clinical question. This information can come from systematic literature reviews; information from randomized clinical trials is the gold standard. The prior probability of dental caries—the likelihood that a person with a given dental and medical history and certain sociodemographic characteristics actually has a carious lesion—is an important starting point. Based on an initial estimate of the likelihood of disease, the prior probability for a particular patient is revised upward or downward based on the findings from the clinical examination and other diagnostic tests that may have been ordered, yielding a posterior probability of disease. The clinician either explicitly or implicitly establishes some probability of disease at which he/she is indifferent between giving treatment and withholding treatment. This probability is referred to as the treatment threshold. If the posterior probability of disease is below the treatment threshold, then no treatment should be provided; if it is above the treatment threshold, treatment should proceed. The efficacy and/or effectiveness of alternative treatments should guide the selection of treatment options, which is largely determined by the outcomes associated with those courses of treatment, including patient preferences for certain treatment options or health states. Quality-

adjusted life years (QALYs),[9,10] or the dental corollary—quality-adjusted tooth years (QATYs)[11,12]—have been used to incorporate patient preferences into the analyses.

Finally, in the fourth step, a preferred course of action is chosen, based on the decision tree structure and relevant probability and outcome data. Synthesis of this information does not identify a "correct" course of action, but rather a "preferred" course of action that would yield the best outcome given the information available and assumptions made in the analysis. Because there may be uncertainty associated with the probability and outcome estimates and with the structure of the tree itself, a sensitivity analysis must be done to assess the impact of uncertainty on the conclusions. Such analyses examine the stability of conclusion using a range of probability and utility estimates and structural assumptions. In some instances, the preferred course of action is robust over a wide range of probability and outcome estimates. In other cases, the preferred course of action changes within a narrow—and clinically important—range of probabilities and outcomes, suggesting that additional information is needed to make the treatment decision.

Application of clinical decision-making to caries management

The Planning Committee developed the following questions that are to be addressed by the Consensus Development Conference Panel.

1. What are the best methods for detecting early and advanced dental caries (validity and feasibility of traditional methods; validity and feasibility of emerging methods)?

2. What are the best indicators for an increased risk of dental caries?

3. What are the best methods available for the primary prevention of dental caries initiation throughout life?

4. What are the best treatments available for reversing or arresting the progression of early dental caries?

5. How should clinical decisions regarding prevention and/or treatment be affected by detection methods and risk assessment?

Figure 2 illustrates one model for applying the clinical decision-making framework to address these questions. (The numbered circles in the model correspond to the questions above.) In this model, various aspects of the decision-making process are represented. As in most clinical encounters, the clinician conducts a thorough history and physical examination that includes collection of information on risk and medical and dental histories. This is followed by a visual and tactile clinical examination that may include additional diagnostic tests such as radiographs or bacterial tests. The clinician integrates this information to form a diagnosis (Question 1) and to determine—both explicitly and implicitly—risk for disease progression and future disease at the patient, tooth, and surface level (Question 2).

Based on the diagnosis and risk assessment, the clinician then considers various alternatives for primary prevention of dental caries initiation throughout life (Question 3) or plans treatments for reversing or arresting the progression of early dental caries (Question 4), incorporating patient preferences and expectations and practitioner preferences in each case. Various clinical strategies will result in a (potentially) different outcome(s) that may be measured along biological, clinical, psychosocial, or economic dimensions.[7] By assessing the outcome(s) associated with a particular strategy, including caries detection methods and risk

assessment, one can determine preferred strategies for caries management (Question 5). An important feature of this model is feedback. At each point in the decision process, clinicians can apply new data and revise clinical decisions based on an evolving evidence base. Changes in practice patterns and treatment strategies occur by assimilation and accommodation, which happen as a result of formal learning and feedback from clinical practice.[8]

Discussion

Clinical information is imperfect, both in its content and the strategies used to make sense of it. Despite our best efforts to gather information from clinical practice and to conduct research, decisions will have to be made on probabilistic—not definitive—information. The utility of clinical decision-making approaches such as the one described here is to provide a framework for making decisions to achieve optimal expected outcomes. Diagnostic, effectiveness, and outcome information is quantified and combined in an explicit way to serve as a tool for clinicians, not as a replacement for clinical judgment or experience. Clinical decision-making takes population- or study-based information and applies it to clinical decisions about the management of an individual patient. It allows the user to assess and be mindful of the impact of uncertainty on clinical decisions. Perhaps the most important factor associated with clinical decision-making is the purposefulness necessary to structure a clinical problem, taking into account the uncertainty associated with clinical information and outcomes.

Decision models described here portray a clear diagrammatic sequence of steps in diagnostic and treatment activity that may be very useful for educational or training purposes. However, the use of statistical models has provoked some controversy regarding whether the clinician or a decision support system such as decision analysis is more efficient in making

clinical decisions.[13-16] In the early days of computer-based systems, such development explored the potential of artificial intelligence for direct use in the clinical environment. Computer programs were found to be more efficient in gathering data to choose between diagnoses than clinicians were,[15] mainly because computers can build and organize larger and more detailed databases.[17] However, to date no software can resemble a clinician's performance to cope with the amount and variety of information needed to solve his/her daily clinical workload issues. The complexity of the clinical decision; the sensitivity and specificity of diagnostic tests; the efficacy and effectiveness of alternative treatment strategies; and the assessment of relevant outcomes (including patient preferences) require time and expertise to assess and analyze using the decision-making approach described here. Until computer-assisted decision-making applications are widely available at the chairside at a reasonable cost, most dental professionals will likely find it difficult to apply these principles on a routine basis. For some clinical conditions, however, a new analysis will not be necessary for each patient; many of the factors associated with certain decisions will be sufficiently uniform to permit application of the approach and findings to a number of patients.

What is aimed to be achieved through designing and implementing individual decision models? Generally speaking, such models can be powerful aids to diagnosis and treatment planning. Such aids usually are frameworks used to structure stages in information management, establish a taxonomy of pieces of information, and allow the re-arrangement of such information throughout the consultation. Frameworks can organize information needed by the clinician to make decisions, thus minimizing the likelihood of error. While previous experience arising from probability-weighted disease patterns or probability-weighted outcomes from diagnostic and therapeutic procedures may not necessarily be relevant to the individual patient, the framework

offered by the clearly structured rationales of decision models supports a more accurate assessment of the probability of treatment.[18] A word of caution is warranted in this regard: individual patients cannot be treated as the average of the group nor as the representative sum of the group in a person. Decision analysis may give the erroneous impression that (i) previous epidemiological and clinical experience can be converted into readily accessible databases under reliable probability scores per item; (ii) these databases can reflect each subtle characteristic of the individual case and these characteristics can be translated into probability scores; and (iii) no factors have been left out (a closed universe is assumed). Even with today's available epidemiological information and information-management technology, these assumptions are difficult to sustain.

Such hurdles have not diminished the enthusiasm for decision systems to support decision-making.[19,20] Because the assessments of probability outcomes are dependent on the clinical information available from the masses of patients applied to the individual case, the probability assessment may be mathematically correct and still lead to a wrong diagnosis. Bader and Shugars[18] entered a cautionary note in this regard for the descriptive models of individual restorative decisions they developed with actual patient data. In general, the occurrence of correctly diagnosed cases against incorrectly diagnosed cases would eventually balance to resemble the statistics from which the diagnostic probability algorithms were originally drawn.

Clinical decision-making for dental caries management has the potential to improve clinical practice and help dentists do what they do better by structuring the decision problem and assessing probabilities and utilities.[1] Such approaches helping dentists communicate with each other by structuring clinical controversies, thereby identifying how and why disagreements may arise and what additional data may be needed to address a clinical question. There are

considerable opportunities to enhance the proficiency of clinical decisions using models to support clinical performance *in vivo*, and to implement better training and educational programs. Current information technology offers considerable potential to build life-like, detailed environments whereby the information within the clinical setting can be complemented, or an entire clinical setting created anew in a high-technology environment.

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Table 1. Steps in clinical decision-making

1. Identify and bound the decision problem
    - Alternative actions
    - Possible clinical information obtained
    - Possible clinical states of the patient at different points in time
    - Other considerations
2. Structure the decision problem
    - Decision tree representing logical and temporal sequence of clinical problem
        - Clinical starting point
        - Choices
        - Probabilistic events
        - Outcomes
3. Characterize the information needed
    - Uncertainties
    - Valued outcomes
4. Choose a preferred course of action
    - Synthesis of structure and available information
        - Quantification
        - Sensitivity analysis of conclusions

Figure 1. Decision tree for initial caries management

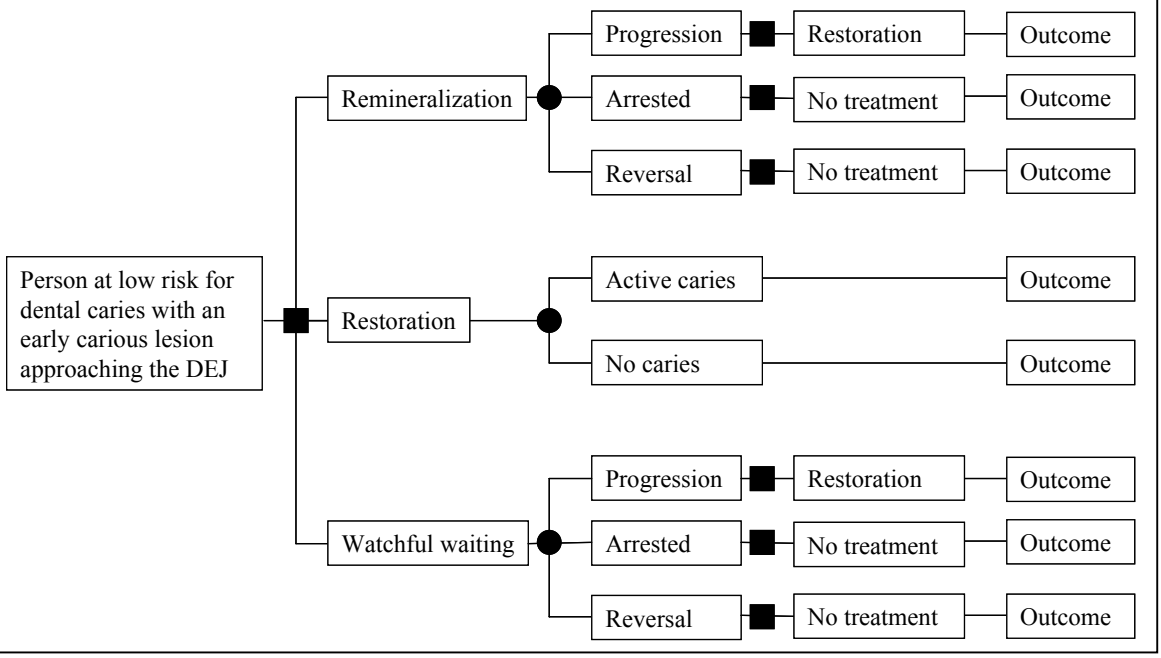

Figure 2. Clinical decision model for caries management